

THE POWER PERFORMANCE EXPERIMENT OF DISH-STIRLING SOLAR THERMAL POWER SYSTEM

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ABSTRACT

The power performance experiment of Dish-Stirling solar thermal power system with and without load are analysed in this paper. The results show: ① The generating power parameters (voltage, current, frequency and power) of the system increase along with the direct normal insolation whether the system is in with-load or without-load condition; ② The required direct normal insolation for the system start is about 450W/m² in without-load condition, and it is about 820 W/m² in with-load condition; ③ When direct radiative intensity decreases to about 300 W/m², the without-load system will stop; ④ The output voltage, current, frequency and power of the with-load system are about 50V, 0.9A, 100Hz respectively when the system is running.

1. INTRODUCTION

Dish-Stirling solar thermal power bases on spot-focused collecting heat and Stirling thermodynamics cycle. The concentration ratio of dish concentrator can reach 1500~3000, and the operating temperature of the receiver

can reach more than 800°C. Reported from literatures, the peak solar-to-electric conversion efficiency of the system has reached 29.4%. Because Dish-Stirling solar thermal power system adopts the idea of modularity generally, it can be used as scattered power source of electric power system, also it can make up dish field to provide electric power assembly. Just as its high efficiency and flexible combinations, it has been developed quickly in developed countries in the last 20 years, and the output power of unit system ranged from 2kWe to 50kWe.

At present, the technology economy properties of Dish-Stirling solar power system have been analyzed inside and outside the nation[1-8], showing this system is in the pre-commercial demonstration stage. Thomas Mancini in San Diego national laboratory made overall summaries on the present conditions and prospects of Dish-Stirling system [9]. The study on Dish-Stirling solar thermal power system is later in China. The study on dishing concentrator in China began in the early 21st century, and the first Dish-Stirling solar thermal power experiment system of which the rated power was 1kWe was established in Institute of Electrical Engineering Chinese Academy of Sciences in March, 2006, and power performance

experiment was established in July in the same year.

2. DISH-STIRLING SOLAR THERAL POWER EXPERIMENT SYSTEM

2.1 Dish Concentrator

Concentrator in the experiment system adopts multi-dish mode. The concentrator is a approximate spinning paraboloid with the whole getting light area of 12.56 m^2 that consists of 16 rotation parabolic reflectors, each 1m dia and 3.25m focal distance. In order to enhance the reflector reflectivity, the silver-plated glass structure by sticking super thin and high reflectivity material on the initial glass structure is adopted.

2.2 Stirling Engine (Power Conversion Unit)

The rated power of the BM1000 Stirling engine bought from Germany is 1kW_e. The engine includes: direct normal insolation tube receiver, Stirling heat engine, generator and water-cooling system. Its structure is shown in figure 1. The start system of Stirling includes: storage battery, motor and relay. The Stirling engine starts by switching the relay manually.



Fig. 1: Stirling engine.

2.3 Testing System

The inlet and outlet temperatures of the cooling system are measured by Pt100 resistance with 4 lines. The precision of the Pt100 resistance is $\pm 0.1\text{K}$.

The flowrate is measured by electromagnetic flowmeter made in ABB, type DE43F, with precision of 0.5%.

The direct radiation meter tracks the sun, measuring the direct normal insolation raying to the concentrator aperture.

Three resistances are used as load of the power circuit, and the resistances are connected in the type of star. The upper limit of the electric current measured by the Agilent data-collecting meter is 100mA, so a 1:50 converter is connected in the circuit to decrease the gross current to measure the current of the load. The voltage can be measured by Agilent data-collecting meter directly.

The measuring data is delivered to the data-collecting meter, collected and supervised timely. The scan period of the data-collecting meter is 10s.

The sketch of the testing system is showed in figure 2. The parameters marked in blue in the sketch need to be measured.

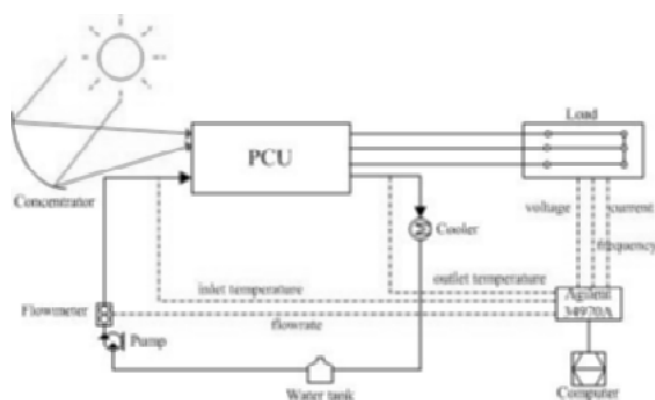


Fig. 2: Sketch of system testing.

2.4 The Whole System Figures and Main System Parameters

Dish-Stirling solar thermal power system is shown in

Figure 3. Parameters of the system are summarized in Table 1.



Fig. 3: Dish-Stirling solar thermal power system-concentrator.

TABLE 1: MAIN PARAMETERS OF DISH-STIRLING SOLAR THERMAL POWER EXPERIMENT SYSTEM

CONCENTRATOR	
Type	spinning paraboloid
Projection Area/ m ²	0.785
No. of Reflectors	16
Equal Diameter / m	5
Focal Distance / m	3.25
Reflector Width/ mm	1
Reflector Reflectance/ %	90
Tracking Control	Two-axis Tracking
Geometric Concentration Ratio	400.12
STIRLING ENGINE	
Type	BM1000 (made in Germany) 1kWe
Receiver Type	DNI Tube Receiver

3. POWER PERFORMANCE

Figure 4 shows the power performance of without-load system. From Figure 4(a) we can see: when the peak DNI is about 400W/m², the Stirling engine cannot startup even if it receives solar radiation concentrated by the concentrator continuously. When the DNI reaches more than 450 W/m², the Stirling engine will startup and run stably as shown in Figure 4(b). The generating voltage of without-load system increases along with the increase of the DNI. When the DNI decreases to less than 300 W/m² suddenly, the Stirling

engine will stop running. Comparing Figures 4(b) and 4(c) we can see when the solar insolation is about 450 W/m², the generating voltage of the without-load system is 70V, and when the DNI reaches 750 W/m², the generating voltage of without-load system is 100V. As shown in Figure 4(c), when solar DNI is about 800W/m², the Stirling engine can startup after rayed five minutes. The reason of the sudden voltage decrease in the figure is that the pump room is cut power, and in order not to overheat the Stirling engine the concentrator is deviated the focus. The same as what showed in Figure 4(b), when the DNI decreased to less than 300 W/m², the system stops running. Figure 4(d) shows the generating frequency of the system increases along with the increase of DNI.

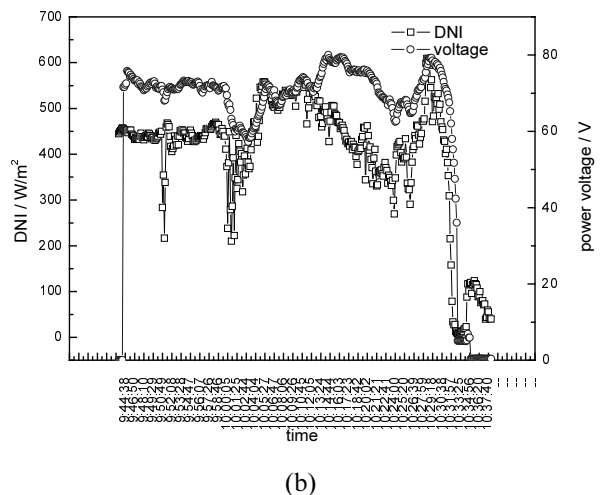
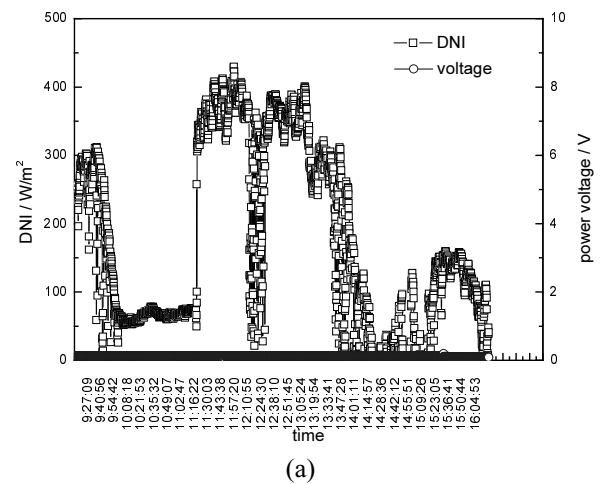
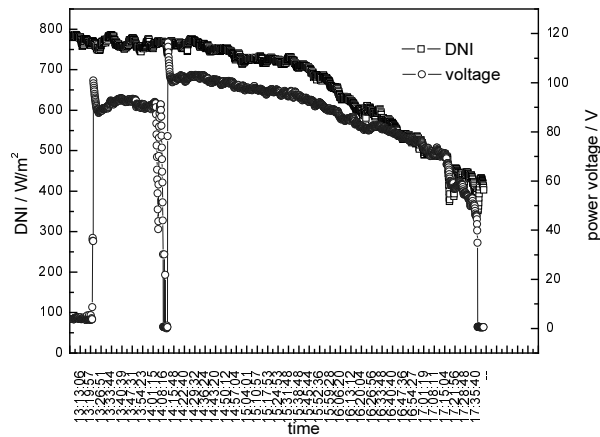
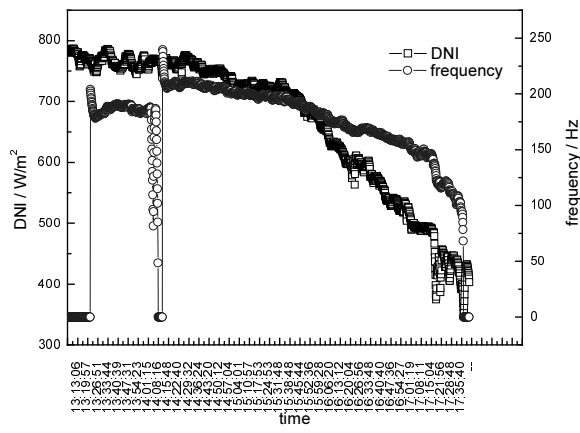


Fig. 4: Dish-stirling system without-load power experiment.



(c)



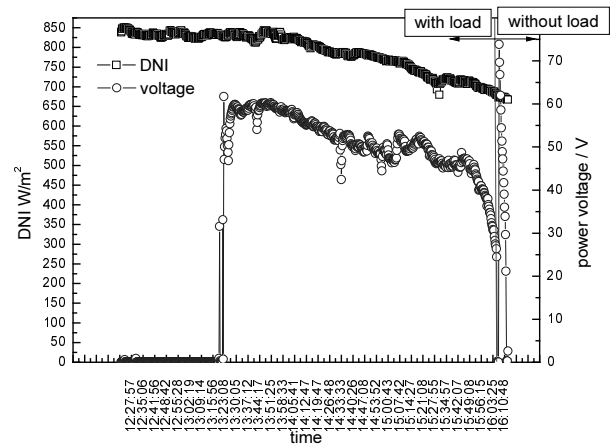
(d)

Fig. 4 (continued)

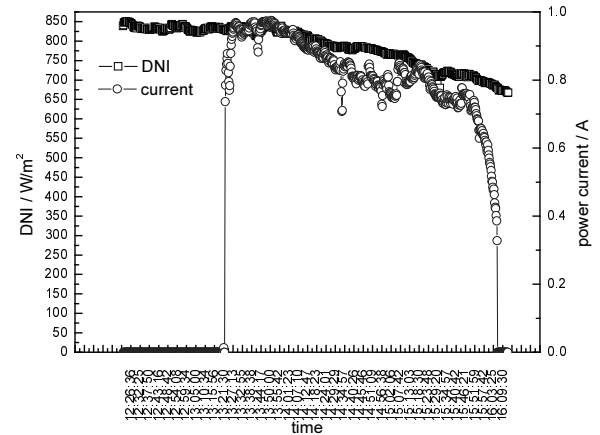
In a word, in Dish-Stirling solar thermal power experiment without-load system, when the DNI increases the generating voltage and frequency will both increase. The system can run stably when DNI is more than 450 W/m² until the DNI is less than 300 W/m².

Figures 5(a) ~ (c) show the characters of voltage, currency, frequency and power of Dish-Stirling solar thermal power system with load connected in star vary according to solar insolation. The results showed that they have the common changing regulars with varying DNI, that is they will increase along with the increase of the DNI. When the direct normal insolation is about 820 W/m², the system can startup with load. The system generating power is about 50V, the currency is about 0.9A, the frequency is about 100Hz and the power is about 80W. Because the direct normal insolation was better that day, the Stirling engine

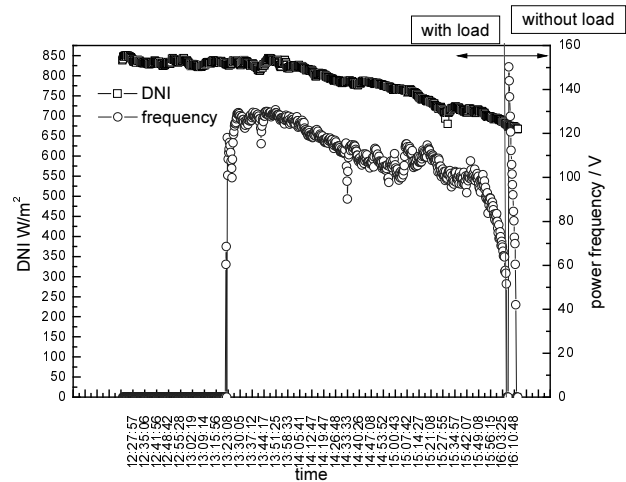
was running stably after starting.



(a)



(b)



(c)

Fig.5: Dish-stirling system with-load power experiment.

4. CONCLUSIONS

Though the Dish-Stirling solar thermal power experiment system in this paper has a long distance from the prototype system abroad from the view of generating power and efficiency of the system, through the experiment study of the system and the heat performance dish concentrator we can know as core components dish concentrator and two-axis tracking control technologies can satisfied the use requirements, and the Stirling engine technology which is fit to solar thermal power is the restriction of the development of Dish-Stirling thermal power technology in China.

5. REFERENCES

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